(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 November 2001 (22.11.2001)

PCT

(10) International Publication Number
WO 01/87052 A2

(51) International Patent Classification[7]: A01K

(21) International Application Number: PCT/NO01/00207

(22) International Filing Date: 18 May 2001 (18.05.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
20002602 19 May 2000 (19.05.2000) NO
20004513 8 September 2000 (08.09.2000) NO

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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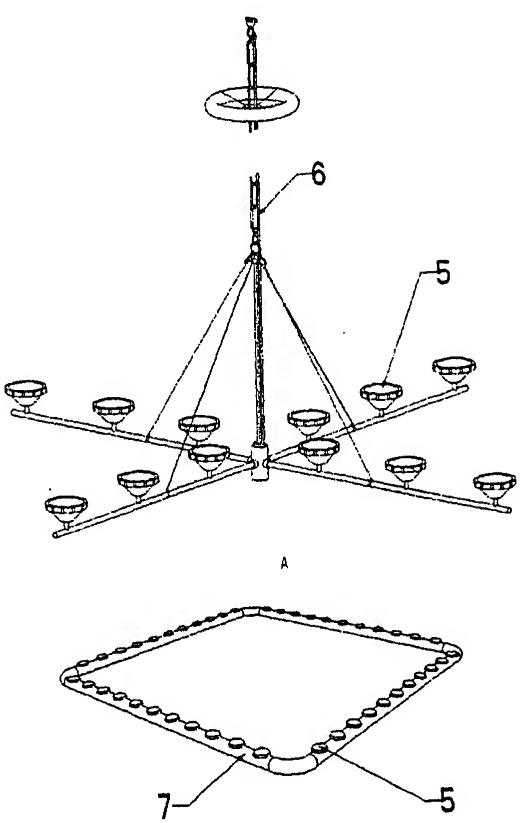
(54) Title: DEVICE FOR OXYGENATING WATER



(57) Abstract: The present invention relates to a device for oxygenating water in aquaculture plants for marine organisms in the sea, together with a method for using the device. The invention provides for the supply of substantially pure oxygen which is distributed via a specified system to the water. Here given devices arrange for the formation of oxygen microbubbles with an oxygen partial pressure which is such that the oxygen passes into the water in the aquaculture plant. The distribution of oxygen is adjusted in relation to the water's oxygen saturation.

WO 01/87052 A2

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Device for oxygenating water

The present invention relates to a device for oxygenating water in aquaculture plants for marine organisms in the sea by means of oxygenous microbubbles, together with a method for using the device.

In many sea water fish farms, low oxygen levels are recorded during certain periods. Reports have been received from some fish farmers that the oxygen content during these periods can be as low as 3-4 mg/litre at 14-15°C, corresponding to an oxygen saturation of only 40%. The periods may be of shorter or longer duration, and occur particularly when the sea temperature is high, after feeding, and during the evening/night when the respiratory activity of the algae is high.

With an oxygen saturation as low as that mentioned above, the fish have difficulty in surviving. A fish farmer will notice that the fish is not eating and tends to move to the upper layers of the water and gasp for oxygen. In general low oxygen saturation will result in a reduction in both feed utilisation and growth, and experiments have shown that even an oxygen saturation as high as 85% can give this result, although without the loss of appetite or altered behaviour in the fish. Thus the problems associated with low oxygen saturation can occur without a farmer noticing any obvious symptoms in the fish.

Fish are ectothermal animals whose metabolism depends on the temperature of the sea. A high sea temperature produces a high metabolism, good appetite and mobility. This leads to a high oxygen requirement which has to be covered from the surrounding water masses. If the oxygen saturation in the water masses is low, it will lead to reduced metabolism. Reduced metabolism leads to a lower growth rate, poorer utilisation of feed since the feed is not absorbed but is pushed through the gut without being digested, and reduced resistance to disease.

During the period July - October, it is assumed that it is the availability of oxygen which is the limiting factor for maximum feed utilisation and growth in sea water. If it had been possible to increase this to normal saturation during periods of low oxygen saturation, substantial gains could have been obtained in the form of lower feed factor, increased rate of growth, increased production capacity (higher fish density) and greater resistance to disease as

a result of less environmental stress. No known solutions exist at present, however, which enable generator-produced oxygen to be added in an efficient manner, in large amounts and over lengthy periods to water in open cage installations.

Equipment exists at the present time for oxygenating water for farmed salmon and trout, while the fish still are located in land-based installations. In this case the water source is principally fresh water which flows by means of gravity into the fish farm. During the period when the fry have to be adapted to life in the sea (smoltification), sea water is gradually added to the plant. Both the water sources require oxygenation, and this may be implemented mainly in two ways; oxygenation in pressurised water systems (a cone, tank or the like with a sufficiently high pressure to enable the gas(es) (oxygen plus some nitrogen) to be dissolved in the water and bind to the water molecules), or diffusion by means of small bubbles (microbubbles). However, neither of these two oxygenation methods is suitable for oxygenation of aquaculture plants for marine organisms in the sea.

JP 06046717 describes a system for adding air or oxygen to a pressurised water system/farmed fish. Oxygenation in pressurised water systems, as performed in the land-based plants, however, is not suitable for oxygenation of cages, since it will be extremely expensive to construct and operate a corresponding system out on a cage. Nor is it possible to add generator-produced oxygen directly to a cage (i.e. without first having dissolved the gas(es) in water which is located in a pressurised system) since it could lead to nitrogen oversaturation of the water, which in turn can result in the fish getting "the bends" (gas bubble sickness) and dying.

Two patents describing systems for air admixture on land/in containers in the form of bubbles are US 4 927 568 and US 4 776 127. These involve oxygen admixture in a livewell on a boat and an aquarium, respectively. Diffusion by means of microbubbles, as implemented on the land-based plants, is performed by means of diffusers consisting of a solid material (ceramics, sintered metal or the like). This kind of diffusion, however, is not suitable for diffusion in sea water over lengthy periods since the sea water, which infiltrates the element, will evaporate on the addition of oxygen, and the leftover salts will in time clog the pores of the diffuser elements.

US patent 3 970 731 describes a diffuser for producing bubbles, where the diffuser is submerged in a liquid. The diffuser is equipped with special recesses whose object is to collect the bubbles from the diffuser pores before they are released into the environment. Consequently, the point of this diffuser is not to release microbubbles, as is the case with the present invention, but to release bubbles which are larger than those emerging from the diffuser pores.

In connection with the removal of salmon lice, ceramic diffusers are employed to-day for brief periods (2 hours - 1 day) for adding oxygen to cages. This oxygen admixture is carried out in this manner since the cage(s) which have to be treated are closed by a tarpaulin before chemicals which kill the lice are added, and closing the cages in this way results in a reduced water through-flow and stressed fish. As already mentioned, however, such (ceramic) diffusers are not suitable for diffusion in sea water over long periods, and there is no permanent system in use to-day for oxygenating cages in the sea.

During periods (July - October) with oxygen saturation values under 85%, approximately 0.65 kg of oxygen supplied to the fish will give approximately 1 kg extra amount of fish produced. This can give an increase in productivity of 5-20%. At a location where 1000 tons of fish are produced, therefore, after deducting the costs of increased oxygen supply, a profit of around NOK 2-6 million may be involved. The fish farming industry is therefore in a situation where the gains, both environmental and financial, make it desirable to have a device which can arrange for the supply of oxygen to sea water in cages.

Thus it is an object of the invention to provide a device for oxygenating water in aquaculture plants for marine organisms in the sea by means of oxygenous microbubbles, together with a method for using the device.

This object is achieved with the present invention, characterized by what is set forth in the attached claims.

The invention relates to a device, together with a method for using the device, which enables oxygen to be added in the form of microbubbles in an efficient manner, and in large amounts, to sea water in open cage installations. For this purpose an oxygenation system is employed where the three main elements are oxygen production (possibly using liquid oxygen

from a cryotank), oxygen admixture by means of diffusion of oxygenous microbubbles and (possibly) control/adjustment of the oxygen admixture.

The present device and method for using the device may also, optionally with minor adjustments which will not be material to the actual concept of the invention, be used to oxygenate sea water in aquaculture plants of other types, such as for example aquaculture plants for shellfish or crayfish.

The invention will now be described in more detail with reference to figures and examples.

Figures 1a) and b) illustrate an air compressor/air dryer 1, a storage tank for air 2, an oxygen generator 3 and a pressure tank for oxygen 4.

Figure 2a) illustrates a diffuser device composed of diffuser elements (diffusers) 5 and diffuser struts 6, and 2b) illustrates a diffuser device composed of diffusers 5 and a diffuser frame 7.

Figure 3 illustrates a dismantled diffuser with a rubber disc 8 and holes 9 for the intake of oxygen.

Figure 4 illustrates one embodiment of a pressure equaliser 10 in a dismantled diffuser.

Figure 5 a) is a view illustrating how the oxygen admixture is implemented by means of a pump 11, a valve 12, an ejector 13 and a distributor pipe 14, and 5 b) illustrates a distributor pipe 14.

Figure 6 a) illustrates a cross section of a non-return unit in an ejector consisting of a chamber 15 and a perforated hose 16, and 6 b) is a perspective view of the ejector.

Figure 7 a) is a flow chart illustrating oxygen production 17, oxygen probes/measurement 18, oxygen control/PLS 19 and oxygen admixture 20, and 7 b) is a general view of oxygen production 17, oxygen probes/measurement 18, oxygen control/PLS, oxygen admixture 20 and oxygen dosing 21.

Figure 8 illustrates cages 1 and 2 together with measuring points for oxygen saturation before (A-G) and after (a-d) oxygen admixture.

Figure 9 (i) illustrates the oxygen saturation at points (A-G) in cages 1 and 2 before oxygen admixture, and 9 (ii) illustrates the oxygen saturation at points (a-d) in cage 1 after oxygen admixture.

Figure 10 illustrates cages 1 and 2 together with measuring points for oxygen saturation before (I-VIII) and after (I-IV) oxygen admixture.

Figure 11 illustrates the oxygen saturation at points (I-IV) in cage 2 before (the bars on the left) and after (the bars on the right) oxygen admixture.

The oxygen which has to be added to the cage is produced on the spot by means of oxygen generators. Air is sucked into an air compressor 1, where it is dried and filtered. The dried and filtered air is then passed to a storage tank for air 2, which is a pressure tank for intermediate storage of pure air. The pure air is then passed to an oxygen generator 3, which by means of a separation medium produces oxygen. This is carried out by forcing the air by means of overpressure into a tank containing a porous material (ceolite). This material will adsorb the nitrogen, while the oxygen passes on to the second tank in the oxygen generator 3. In this way oxygen is produced efficiently and cheaply. The method is called Pressure Swing Adsorption (PSA). The gas which is produced is stored in a storage tank (pressure tank) for oxygen 4, before being further distributed.

The oxygen gas which is produced in this manner has a purity of approximately 90-95%. The remaining 5-10% is mainly nitrogen and argon. In order to avoid nitrogen oversaturation of the water, and thereby the bends in the fish, when this oxygen is added to the sea water, this admixture must be performed in the form of bubbles. Since nitrogen is underrepresented inside a bubble, only nitrogen will pass from the water into the bubble, and consequently no nitrogen oversaturation of the water will occur.

According to the present invention the bubbles which are added to the sea water are oxygenous microbubbles. Amongst the advantages of adding oxygen in the form of such microbubbles are their ability to "float" in the water and their low climb speed, which results in a uniform distribution of the microbubbles/oxygen in the water which has to be oxygenated, and a relatively long contact time with this water. Since large bubbles rise more quickly to the surface than small bubbles, the distribution of the oxygen in the water will not be equally good when adding large bubbles. In addition,

the mass transport (diffusion via the bubble membrane) will be greater for small bubbles compared to large bubbles, since small bubbles have a large surface to volume ratio.

Liquid oxygen from a cryotank (LOX) may also be employed for oxygenation of open cages and therefore should not be ruled out as an oxygen source, but this will not represent a very cost-effective alternative with to-day's aquaculture plants. Such oxygen often has a purity of about 99.5%, but the purity of the oxygen is however of no substantial importance when it is added in the form of microbubbles. However, the addition of pure air (about 20% oxygen) to the water in the cages will not be suitable since it will lead to an increase in the partial pressure of N_2, thereby exposing the fish to the bends.

As a result of the partial pressure difference between the oxygenous microbubbles and the oxygen in the water, the oxygen in the bubbles will very rapidly diffuse from the bubbles into the water, and then on into the fish's gills and blood. Consequently, by means of the present device and according to the present invention, a driving gradient is created, since the partial pressure of the oxygen in the bubbles is greater than in the water, which in turn has higher partial pressure than the fish's blood. The higher the partial pressure difference, the more rapidly and efficiently the diffusion process goes. The partial pressures of other gases (than oxygen) in the bubbles are low, which means that gases such as nitrogen, carbon dioxide and ammonia (NH_3) will only diffuse into the bubbles. These are gases which are considered to be limiting for the fish's growth, and which in this manner are removed from the water when the bubbles "burst" on the surface of the water. This effect thereby provides a further advantage of the use of the present method.

Oxygen from the storage tank 4 is distributed by means of hoses and pipes to each individual cage. In the cage oxygen is added by means of diffuser elements (diffusers) 5 which are attached to a suitable device 6, 7 which is lowered into the sea. Since cages may vary in shape and volume, it may be expedient to employ different types (alone or together) of attachment devices for the diffusers. According to the present invention, attachment devices with mounted diffusers (diffuser devices) are exemplified by diffusion struts (diffuser struts) 6 or diffusion frames (diffuser frames) 7. If the cages are

very large there will be a need for extra, transverse pipes with mounted diffusers inside the frame (not shown).

The ideal position for a diffuser device is such that bubbles pass through the entire horizontal cross section of a cage. The area of the cage which should be covered by diffusers will vary, however, and depends amongst other things on the local water through-flow in, and the depth of, the cage. Both the diffuser frame and the diffuser strut should be adjustable in relation to the water depth at which the oxygen requires to be added, e.g. by means of a wire, rope, hook and/or pulley system which is suspended over the cage, or by means of attachment points (attachment devices) in the actual supporting structure of the cage. The oxygen may be added at a depth of from 2-25 metres, but the most expedient depth to add the bubbles will be from 5-10 metres.

A diffuser consists of a rubber disc/sheet 8, preferably EPDM (ethene propene rubber) which has an elasticity of 40 Ø (shore). This disc is mounted in a frame and sealed with a lock ring (nut). In the rubber disc there is moulded an O-ring which effectively prevents gas leakage. The diffuser is designed with a view to preventing water from flowing back and into it. If sea water infiltrates a diffuser, the water will quickly evaporate (due to the oxygen's 100% dryness), and the salts will be left in the diffuser. In time this will block the diffuser and its oxygen-supplying properties. In this concept, therefore, the diffusers are made of rubber which has resilient properties, and which has resistance to salts, oxygen and sunlight. The resilient properties of the rubber are explained by the rubber disc being equipped with several small holes. When oxygen is added through the supply hole 9 in a diffuser, a pressure is created inside the diffuser, causing the holes in the rubber disc to be opened (because the rubber is stretched), and the oxygen which is thereby forced out of these holes forms small oxygenous microbubbles. The extent to which these holes are opened depends on how much pressure is employed, i.e. how much oxygen gas is added. If no oxygen supply takes place, the holes in the rubber disc will be closed, thus shutting out the sea water.

On account of the rubber disc's great elasticity and the normally low counterpressure over the membrane, problems can easily arise if a diffuser frame or a diffuser strut are exposed to vertical movements. The problem is due to the fact that the oxygen gas being distributed chooses the path of least

resistance, with the result that it emerges at the highest point at any time on a diffuser device. An enormous load is therefore placed on the one or the few diffusers from which the gas thereby emerges, thus forming large instead of small bubbles. Said problem can be countered by constructing a counterpressure over the diffuser membrane, and thus the applicant has designed a pressure equaliser 10, according to the present invention, for this purpose.

A pressure equaliser 10 may be installed in the hole 9 where the oxygen gas flows into a diffuser. In this hole is placed a nipple, and inside the nipple is mounted a transition piece which in turn is connected to a circular rubber hose. The entire arrangement is mounted in such a manner that the rubber hose is located inside the diffuser 5. The rubber hose is perforated by a certain number of holes, thus producing a pressure difference of 0.2 - 2.5 bar over this hose. The oxygen gas thus flows from a distribution pipe into the diffuser through this perforated hose, and continues out of the diffuser over its perforated rubber disc. A pressure equaliser of this kind inside each individual diffuser results in a uniform distribution of the gas between all the diffusers, and the bubbles which are formed over the diffuser membrane are of approximately the same size. With such a pressure equaliser, moreover, the distribution of the oxygen gas will not be influenced by any vertical movements of the diffuser device.

Other embodiments of the pressure equaliser comprising perforated rubber material are also possible, such as e.g. a perforated rubber disc/membrane located in the oxygen flow or a cylindrical perforated rubber body.

Another way, according to the invention, of achieving uniform distribution of the oxygen gas between the various diffusers, may be to reduce the diameter of the hole 9 through which the oxygen gas enters the diffuser.

The oxygen from the storage tank 4 may also be added to the cage by means of a pump 11, a valve 12, an ejector 13 and a distributor pipe 14, and this is providing a further embodiment of the invention. This method of oxygenating cages is based on water which is pumped up into the plant, and pipe trenches which provide for distribution of this water through one or more outlets to each individual cage. At each such outlet is mounted an ejector 13 which ensures that the water velocity in the narrowed area is very

high (10-15 metres/second). Oxygen which is added to the water flow in this narrowed area is immediately broken down into tiny bubbles (microbubbles), and the water with these oxygenous microbubbles is passed on in pipes floating on the surface of each individual cage. At a suitable location in the cage there is a 90 degree bend in the pipe (see Figure 5 a)), with the result that it continues in the vertical direction to a desired depth, e.g. 2-10 metres, preferably 5-9 metres. In this vertical pipe holes are drilled on several "tiers" and in several directions in each tier (see Figure 5 b)). By this means microbubbles will flow out at several depths and in several directions at each depth simultaneously, thus providing a uniform distribution of the oxygen in the cage. The number of tiers, number of holes and the diameter of each individual hole may, e.g., be 2-6 tiers, 2-6 directions and 5-50 mm respectively, preferably 3-5 tiers, 3-5 directions and 10-25 mm respectively, and the dimensions are such that the water with the oxygen bubbles flows out of the holes at a rate of, e.g., 1-6 metres/second, preferably 2-5 metres/second.

In order to prevent a reflux of water into the oxygenation equipment, according to the invention a non-return unit (Figure 6) may be constructed in the ejector area. This non-return unit consists of a chamber 15 (a closed pipe connection of a suitable material, e.g. PVC plastic) and a perforated hose 16. The chamber has connection facilities for an oxygen-supplying hose, and inside the chamber the oxygen distribution continues through a preferably similar, but perforated hose 16. This perforated hose is sealed at the end which fits loosely inside the chamber. From the chamber there is an opening directly to the centre of the ejector, and the oxygen is sucked into the ejector (i.e. the water flow) via this opening and crushed immediately. The oxygen, in the form of microbubbles, is then discharged into the individual cage.

The ideal position for a distributor pipe 14 in a cage will vary depending on the size and shape of the cage in question. One possible solution may be to place a distributor pipe in the centre of a small cage. Another possible solution (e.g. in larger cages) may be four distributor pipes located against the corners of the cage. A variety of designs are also possible for an installation for an oxygenation method of this kind. One such design may be, e.g., to pump water from several pumps into a manifold, whereupon the water is further distributed from this manifold in one or more ring mains around the

installation with one or more outlets (valve, ejector and distributor pipe) to each individual cage.

The water through-flow in a cage may vary greatly. The less through-flow/water exchange which takes place, the greater the need for the supply of oxygen. The water quality in a cage also varies, as does the biomass. In addition, several other parameters will cause the fish's oxygen requirement to vary in the course of 24 hours, and thus through the entire year. It is important to take these variations into consideration when supplying oxygen, and it should be such that an oxygen saturation is obtained preferably of from 41%-85% and more preferably 85%.

According to the present invention such a desired oxygen saturation can be achieved by means of oxygen probes/sensors 18 which are submerged in the water, and which record the oxygen saturation at all times in cages with oxygen supply equipment. The amount of oxygen which is added to a cage (oxygen dosage; 21) is adjusted against a given adjusting point (setpoint), and this setpoint for oxygen saturation is determined in an adjusting unit (a PLS; programmable logic system) 19 or the like, which in turn transmits a signal to a control cabinet 19. Here the adjustment of the amount of oxygen which is added is controlled by means of valves (preferably magnetic valves). From the storage tank for oxygen 17, therefore, all the oxygen gas passes through the control cabinet 19, which then, by means of oxygen dosage 21, distributes/adds 20 the correct amount of oxygen to each cage. Since this system makes it possible to keep an almost constant, and desired, oxygen saturation in the cage, the fish will receive optimal conditions for well-being and growth.

The following examples are intended to illustrate embodiments of the present invention and should in no way be considered limiting.

Example 1: Oxygen admixture with diffuser frame

This example illustrates differences in oxygen saturation in the volume of water in a cage before and after oxygen admixture performed by means of a diffuser frame.

A diffuser frame (9 m^2) with 13 diffusers (9" EPDM rubber, 40 shore) was placed in the centre of cage 1 (Figure 8) at a depth of approximately 7

metres. Cages 1 and 2 (Figure 8) were joined to form a cage of 9000 m^3. This combined cage contained approximately 80 tons of salmon with an average weight of 1.5 kg (density approximately 9 kg/m^3), and the temperature in the cage was 11.3°C. The water was relatively calm, with little surface current, flood tide and overcast weather when the measurements were taken.

The oxygen saturation before oxygen admixture was measured at four points in cage 1 (A-D), and at three points in cage 2 (E-G). The measurements were taken at three depths; 1, 5 and 10 metres. The results of the measurements are shown in Figure 9 (i).

The measurements in cage 1 show surprisingly low oxygen values considering the time of year and water temperature. The values are lowest at depths of 1 and 5 metres; 59% to 69% saturation. At a depth of 10 metres the saturation appears to be generally higher, approaching 83% saturation.

In cage 2 the situation was somewhat different. The saturation is declining from 70% to 39% at point E. At points F and G the values are more stable, being lower at point F (60% to 72%) than at point G (80% to 85%), while the lowest saturation for both these points is at a depth of 5 metres.

The measurements show generally varying and relatively low oxygen saturation values. With increasing temperature in the water and biomass in the cages, the oxygen saturation will probably be even lower. The variations in the measurements also show that the water flow is uneven at different depths.

The oxygen saturation in cage 1 was then measured after oxygen admixture performed by means of the diffuser frame. Since there was not a sufficient counterpressure over the diffuser membranes, the gas emerged only at the highest point on the frame, and it was not possible to adjust the frame in the water in such a manner that the gas was equally distributed over all the diffusers. The gas therefore passed through few of the diffusers/membranes simultaneously (1-3), and the bubbles which were formed were, as previously described, relatively large. Measurements were carried out (points a-d, Figure 8), but they were only made 1-2 metres from the diffusers which produced bubbles. The results of the measurements are shown in Figure 9

(ii), and illustrate that the oxygen saturation in the volumes of water at the measured points, and at depths of 1 and 5 metres, was raised by 10-15%.

The incorporation of a pressure equaliser, as described earlier, in the individual diffuser provided a uniform distribution of the oxygen gas to all the diffusers, and the oxygen was added in the form of microbubbles. The results therefrom are not illustrated.

Example 2: Oxygen admixture with a pump, ejector and distributor pipe

This example shows differences in oxygen saturation in the volumes of water in a cage before and after oxygen admixture performed by means of a distributor pipe.

The oxygen admixture in cage 2 (Figure 10) was performed by means of a pump, ejector and distributor pipe. These measurements were recorded during the transition between ebb and flow (towards ebb-tide), it was windy, slightly overcast with approximately ½ metre high waves.

The oxygen saturation in the volumes of water before oxygen admixture was measured at eight different points (Figure 10; I-VIII), and at three different depths; 1, 5 and 10 metres. The results for measurement points I-IV are shown in Figure 11 (the columns on the left at each measuring point), and for measuring points V-VIII in Table 1.

Table 1. The table shows the oxygen saturation in cage 2 for measuring points V-VIII at three different depths before oxygen admixture.

	Oxygen saturation (%)		
Measuring point	1 metre	5 metres	10 metres
V	72	67	67
VI	68	70	77
VII	71	73	77
VIII	65	65	65

The results show approximately the same variations in oxygen-saturation in the volumes of water as the measurements made the day before (Example 1).

The oxygen saturation in cage 2 was then measured after oxygen admixture performed by means of a pump, an ejector and a distributor pipe. The pump used in the oxygen admixture experiments was placed outside the cage at a depth of approximately 10 metres, and the oxygen saturation was measured here at 70-75%. Oxygen was added to the water which was pumped up as it passed the ejector, and this oxygenous water was then added to the cage, and distributed over ¼ thereof (halfway between points I-IV; Figure 10), by means of a distributor pipe. The measuring points after oxygen admixture (Figure 10; I-IV) were 3-4 metres from the distributor pipe.

The results of the measurements (approximately 1 kg oxygen/hour) are shown in Figure 11 (the columns on the right at each measuring point). At the measuring points I-IV there was an average oxygen increase of approximately 12.5% at a depth of 1 metre. At a depth of 5 metres the increase in oxygen saturation is on average approximately 10.5%. At a distance of one metre from the distributor pipe an oxygen saturation was recorded of up to 120% (data not shown). At higher oxygen dosages (2.4 kg oxygen/hour) oxygen saturations of 90-95% were recorded at the measuring points I-IV (data not shown).

The water with the microbubbles formed a milky cloud of bubbles when they emerged from the distributor pipe, and were dispersed approximately 3 metres from each hole in the distributor pipe. Altogether 9 holes were drilled distributed between 3 tiers (at depths of 1.5, 3.5 and 5 metres) with 3 holes in each tier. Each hole had a diameter of 16 mm. Several smaller holes in each tier would probably give even better distribution of the oxygen bubbles. Microbubbles were observed almost right up to measuring point V. No measurements were carried out at this point, but at measuring point VII there were no significant changes in oxygen saturation before and after oxygen admixture.

PATENT CLAIMS

1. Device for oxygenating water in aquaculture plants for marine organisms in the sea, comprising equipment for the production of oxygen gas and delivery of oxygen gas, with possibly one or more pumps, characterized in that it provides oxygen which is produced on the spot and stored in a suitable tank (4) and that the oxygen is added in the form of oxygenous microbubbles, and that the device further comprises diffusers (5) with or without a pressure equaliser (10), where in the diffusers are mounted on a suitable diffuser device, preferably a diffuser strut (6) or a diffuser frame (7),
or that the device comprises one or more ejector(s) (13) with or without a non-return unit,
one or more distributor pipes (14) and oxygen probe(s) (18) together with a control cabinet (19).

2. Device according to claim 1,
characterized in that the oxygen provided is liquid oxygen from cryotank(s).

3. Device according to claims 1-2,
characterized in that the pressure equaliser (10) consists of different embodiments of perforated rubber material, such as a circular rubber hose which is mounted inside the diffuser by means of a nipple and a transition piece, and that the circular rubber hose is perforated by a number of holes which are sufficient to cause a pressure difference of 0.2 - 2.5 bar over this rubber hose.

4. Device according to claims 1-3,
characterized in that the hole (9) in a diffuser for intake of oxygen has a diameter which is such that the oxygen gas is uniformly dispersed to all the diffusers on a diffuser device.

5. Device according to claims 1-4,
characterized in that various diffuser devices may be employed alone or together, and that the suspension/attachment points for the diffuser device(s) employed are adjustable in such a manner that the diffuser device(s) is placed at depths from 2-2.5 metres, preferably from 5-10 metres.

6. Device according to claims 1-2,
characterized in that the non-return unit in the ejector (13) consists of a chamber (15) with a connection facility for an oxygen-supplying hose on the outside of the chamber and a preferably similar but perforated hose (16) which is sealed at the end which ends freely inside the chamber.

7. Device according to claims 1-2,
characterized in that the distributor pipe (14) which is employed for adding water with microbubbles to the water in the aquaculture plant is submerged to a depth of from 2-10 metres, preferably 5-9 metres, and that this distributor pipe is equipped with holes on several tiers and in several directions in each tier, e.g. 1-6 tiers and 1-6 holes respectively, preferably 2-5 tiers and 2-5 holes respectively.

8. Device according to claims 1 and 7,
characterized in that the holes in the distributor pipe have a diameter of from 5-50 mm, preferably 10-25 mm, or that the dimensions of the holes are such that the microbubbles flow out of the holes at a rate of from 1-8 metres/second, preferably from 2-5 metres/second.

9. Device according to claims 1-8,
characterized in that the oxygen admixture optionally may be controlled/adjusted in relation to the oxygen saturation in the water which has to be oxygenated or a specific adjusting point/setpoint, whereby an adjusting unit/control cabinet (19) receives information concerning the water's oxygen saturation from appropriate oxygen probes/sensors (16).

10. Method for using the present invention for oxygenating water in aquaculture plants for marine organisms in the sea,
characterized by the provision and admixture of substantially pure oxygen in the form of oxygenous microbubbles where the oxygen provided is produced on the spot and stored in a suitable tank (4) or it is provided in the form of liquid oxygen from a cryotank,
the admixture is performed by means of diffusers (5) with or without a pressure equaliser (10), or by means of an ejector (13) with or without a non-return unit consisting of a chamber (15) with a connecting facility for an oxygen-supplying hose and a preferably similar but perforated hose (16)

which is sealed at the end which ends freely inside the chamber (15), and one or more distributor pipes (14).

11. Method according to claim 10,
characterized in that the oxygen is supplied with or without the use of oxygen probes/sensors (16) and an adjusting unit/control cabinet (19).

12. Method according to claims 10-11,
characterized in that the diffusers (5) which are employed are mounted on a suitable diffuser device, e.g. a diffuser strut (6) or a diffuser frame (7).

13. Method according to claims 10-12,
characterized in that by means of adjustable suspension, the diffusers (5) are placed at depths of from 2-25 metres, preferably 5-10 metres.

14. Method according to claims 10-13,
characterized in that the distributor pipe which is employed reaches depths of from 2-10 metres, preferably from 5-9 metres.

15. Method according to claims 10-14,
characterized in that an oxygen saturation is achieved in the water which is in relation to the aquaculture plant organism's requirements, preferably from 41-90%, more preferably 85%.

16. Method according to claims 10-15,
characterized in that the oxygenation takes place in cages or other kinds of aquaculture plant, such as, e.g. plants for rearing shellfish or crayfish.

17. Use of the device as indicated in claims 1-9 for oxygenating water in aquaculture plants for marine organisms in the sea, where in the device is placed at locations and depths in the cage which permit all the water in the cage to receive a desired oxygen saturation.

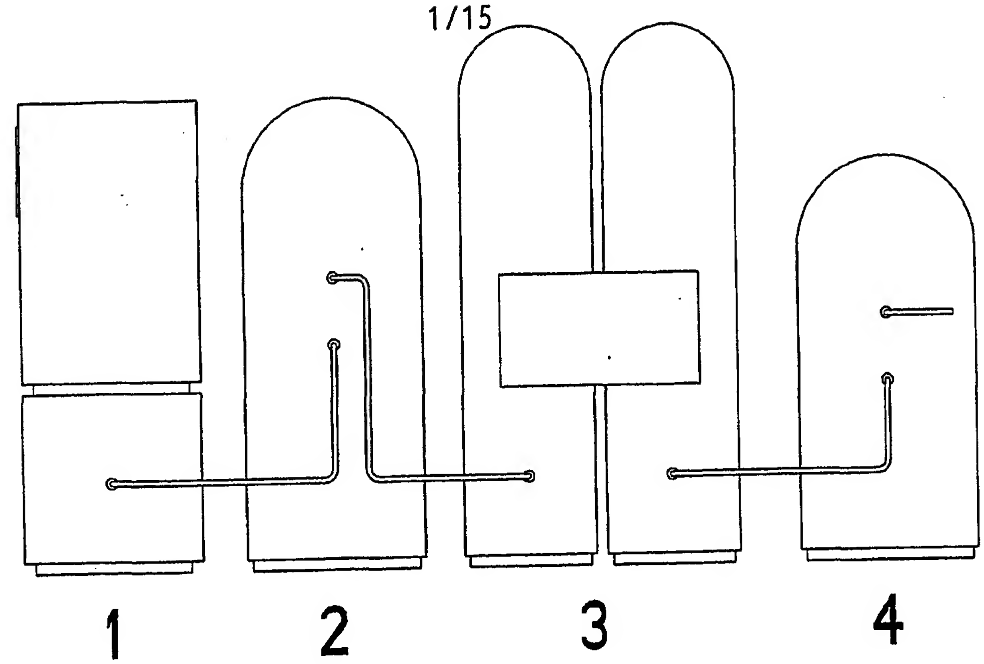


FIG. 1A

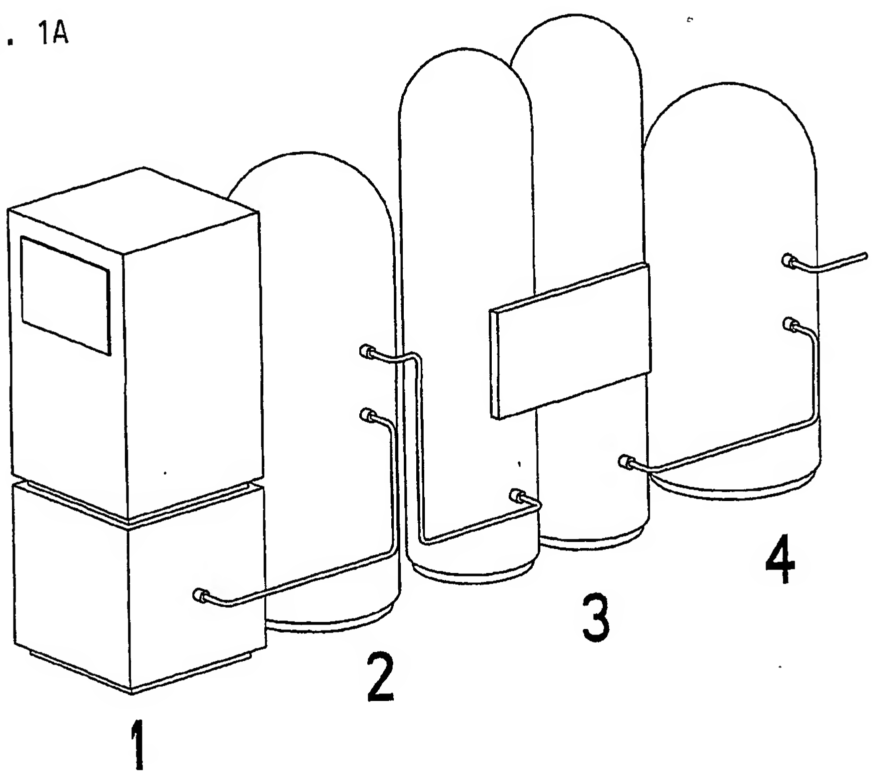


FIG. 1B

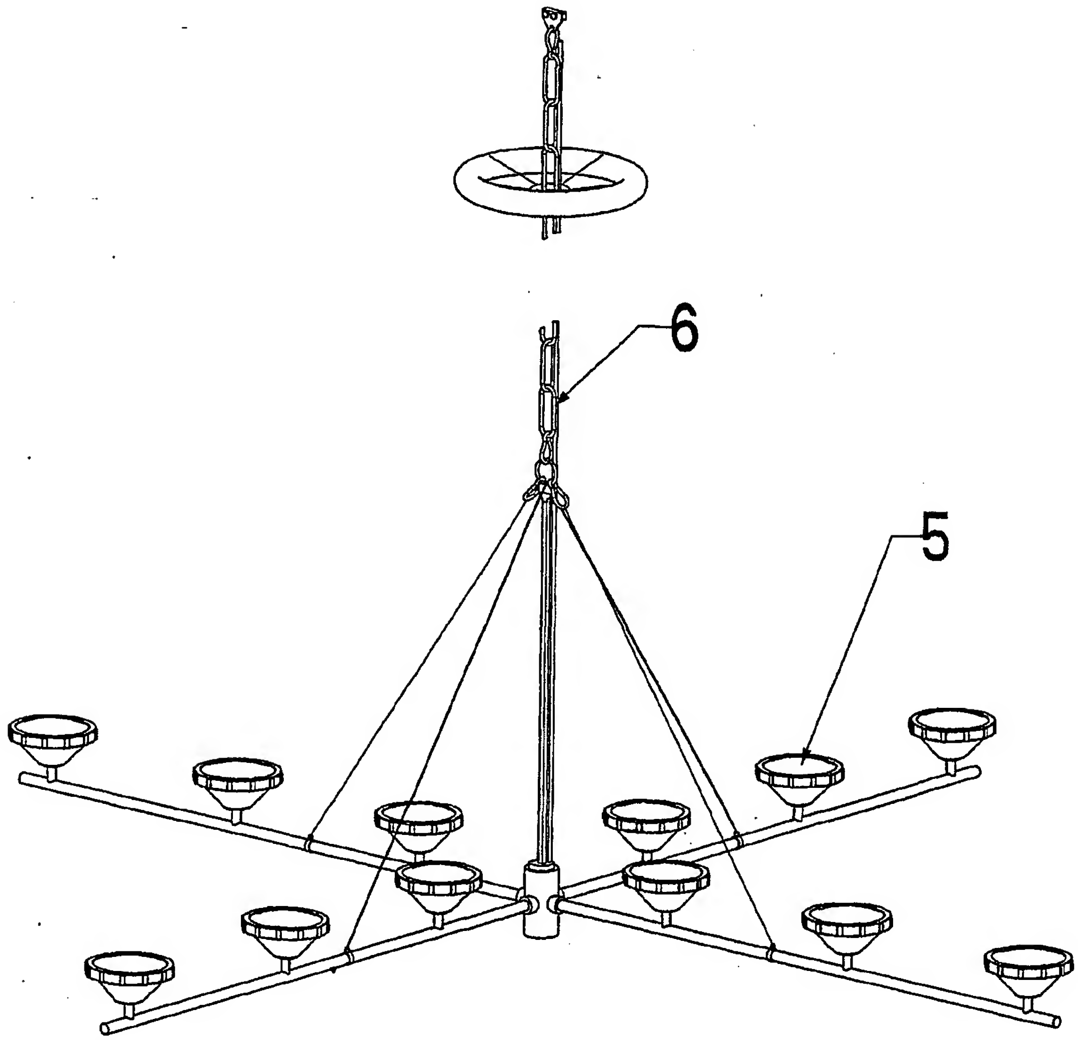


FIG. 2A

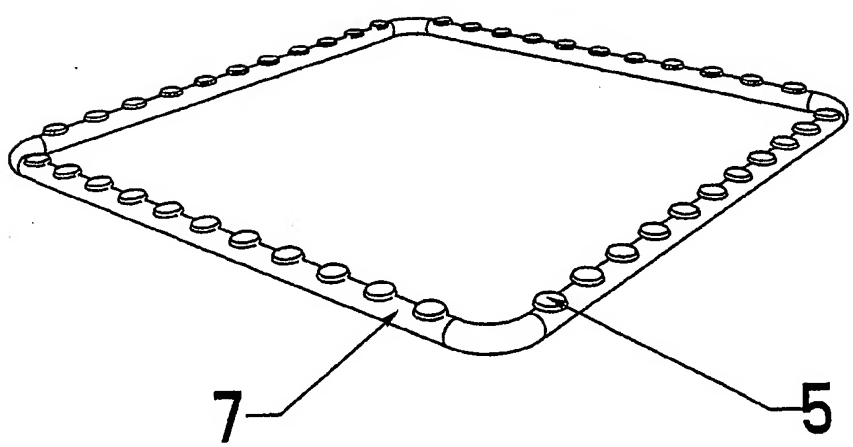


FIG. 2B

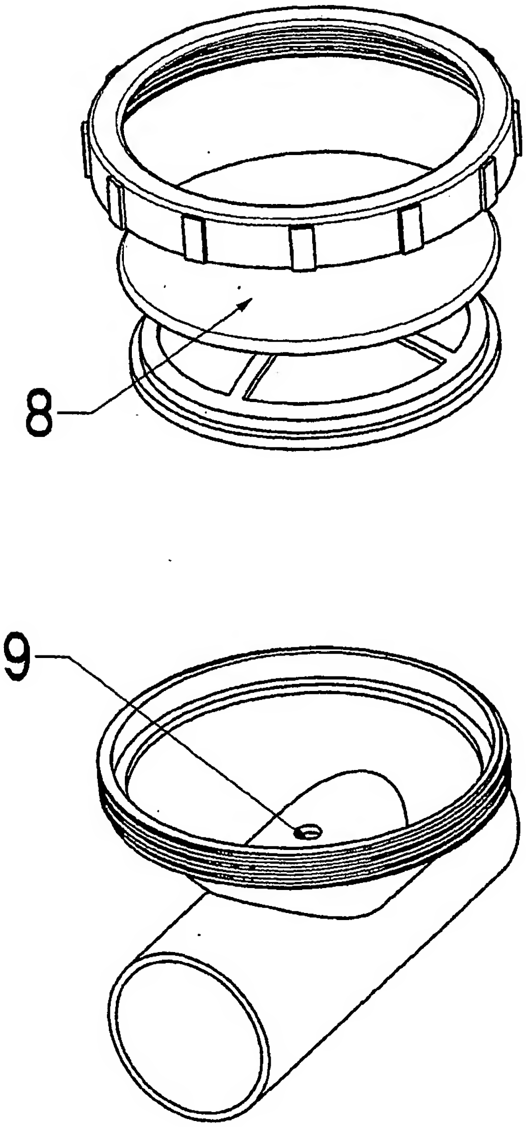


FIG. 3

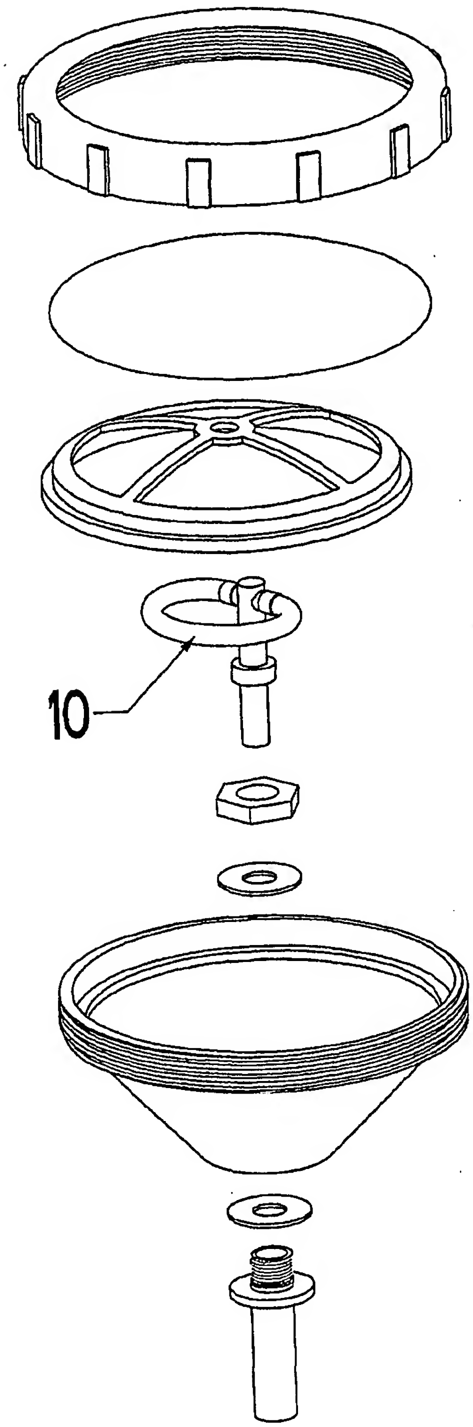


FIG. 4

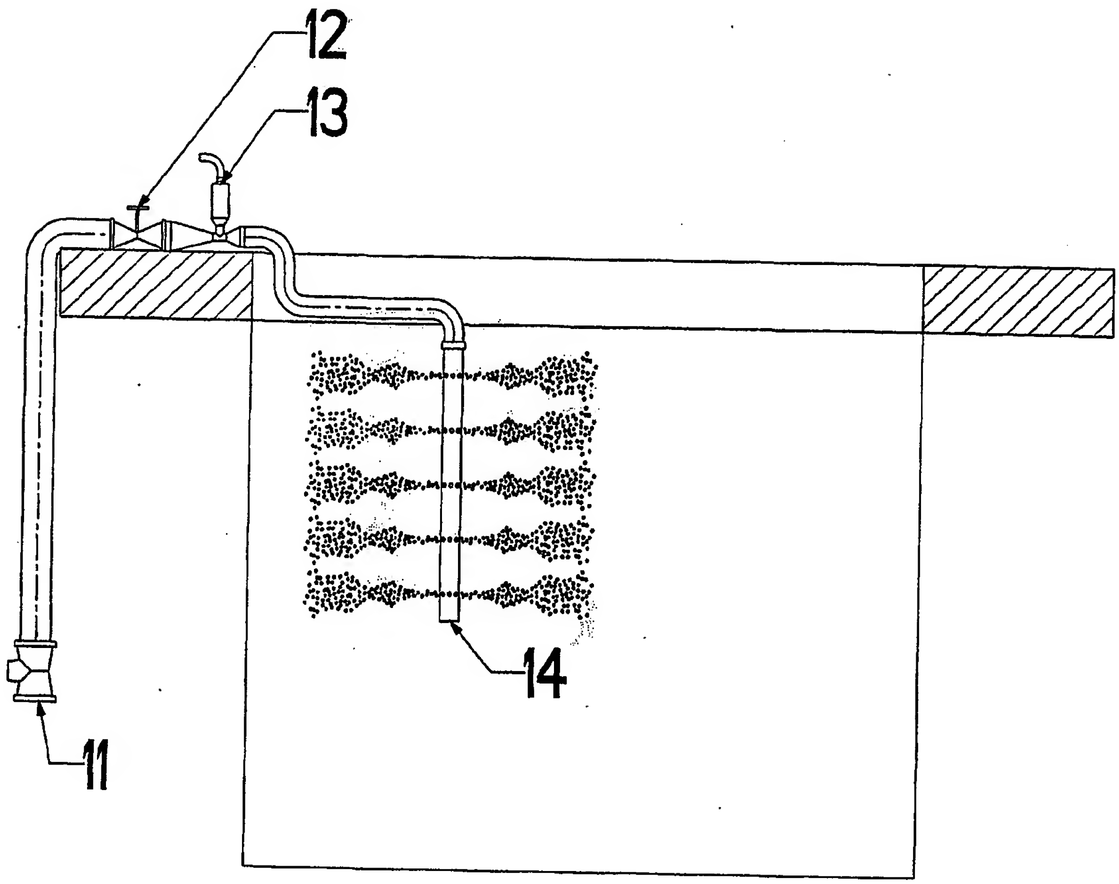


FIG. 5A

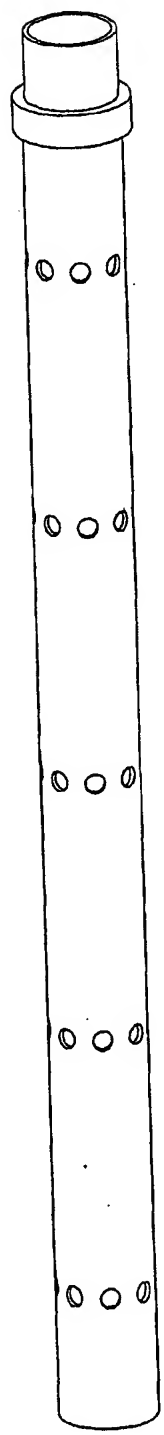
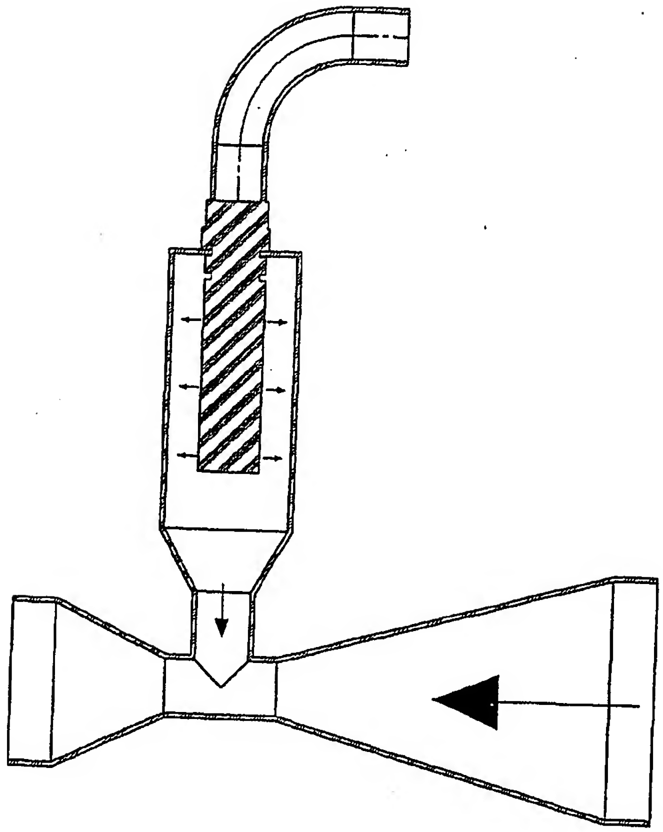


FIG. 5B



SECTION A-A

FIG. 6A

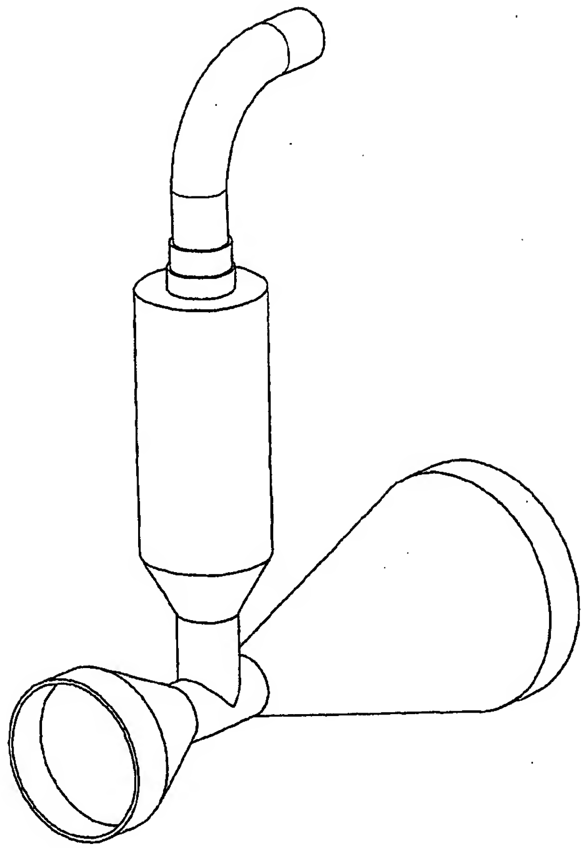


FIG. 6B

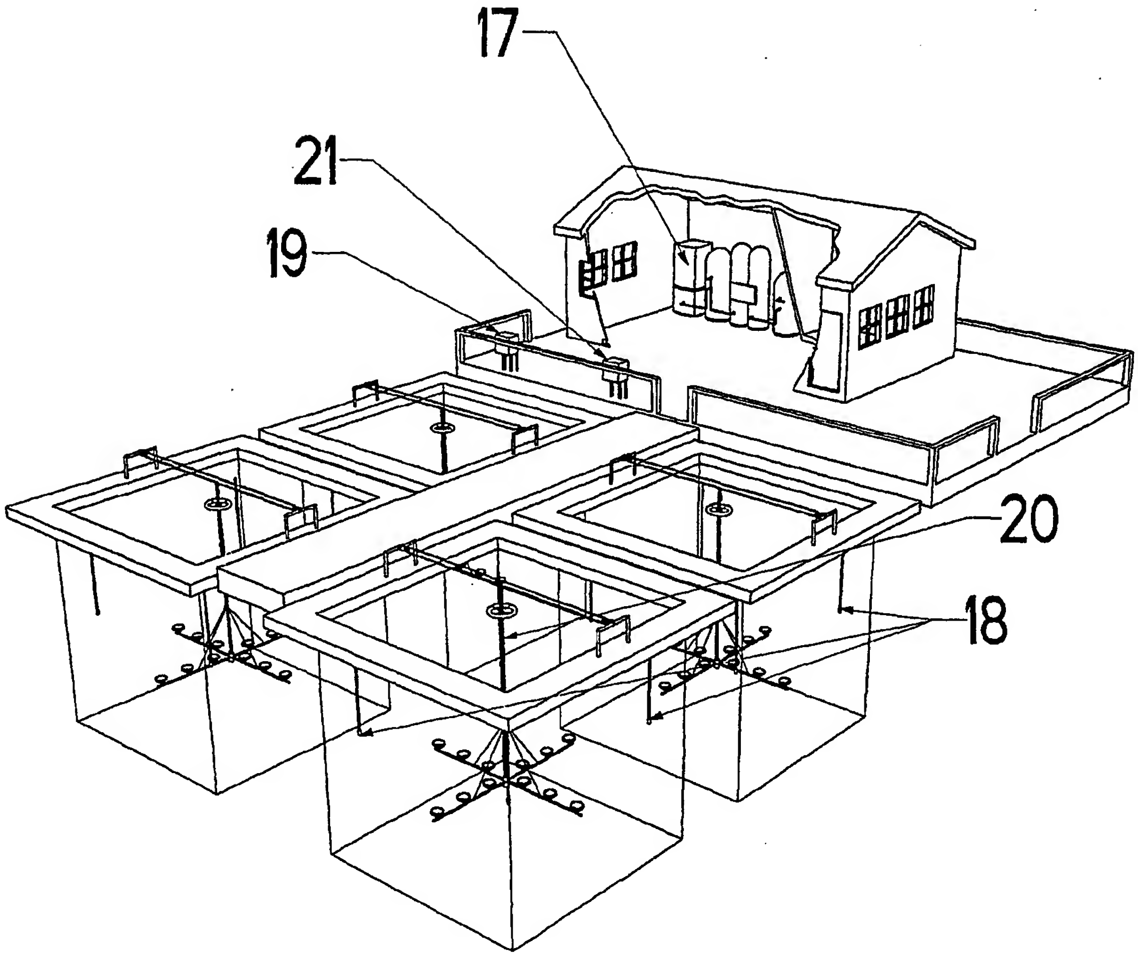


FIG. 7A

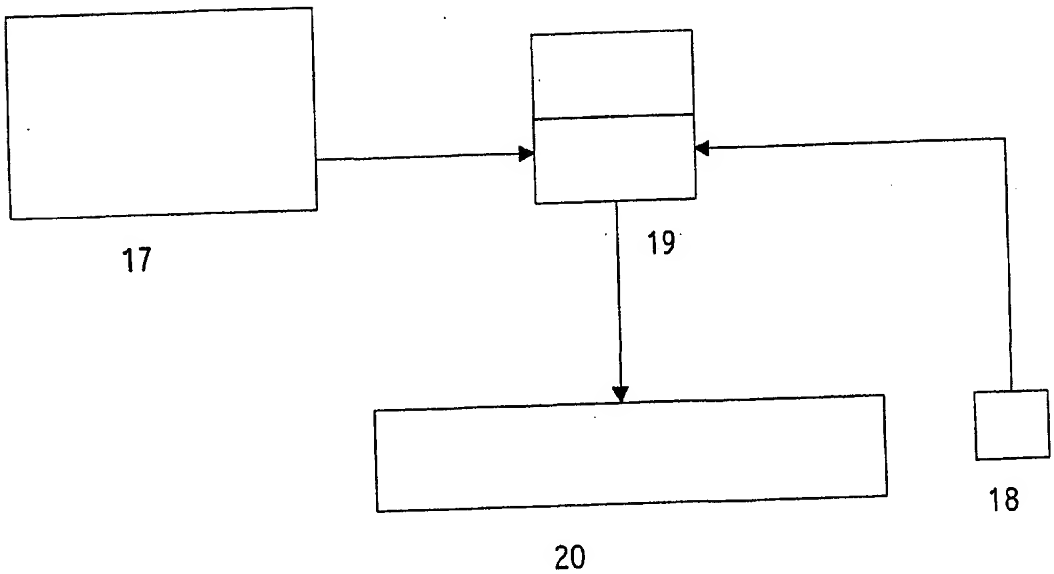


FIG. 7B

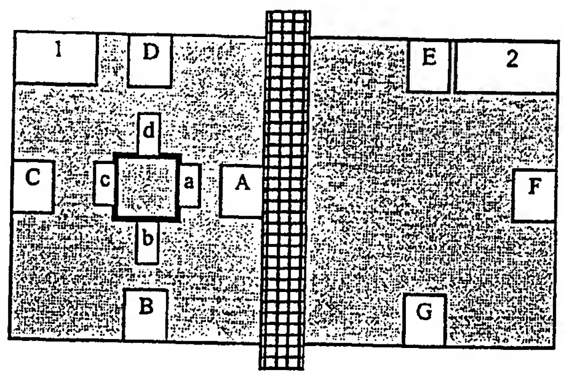


FIG. 8

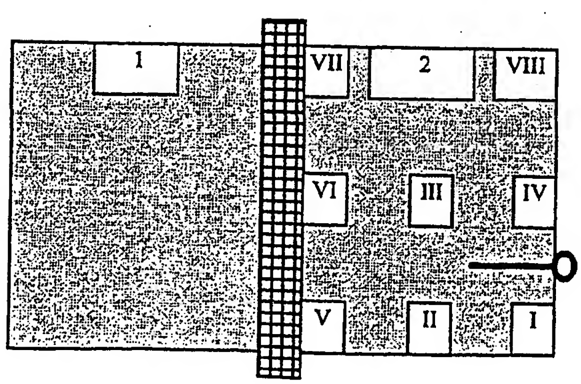
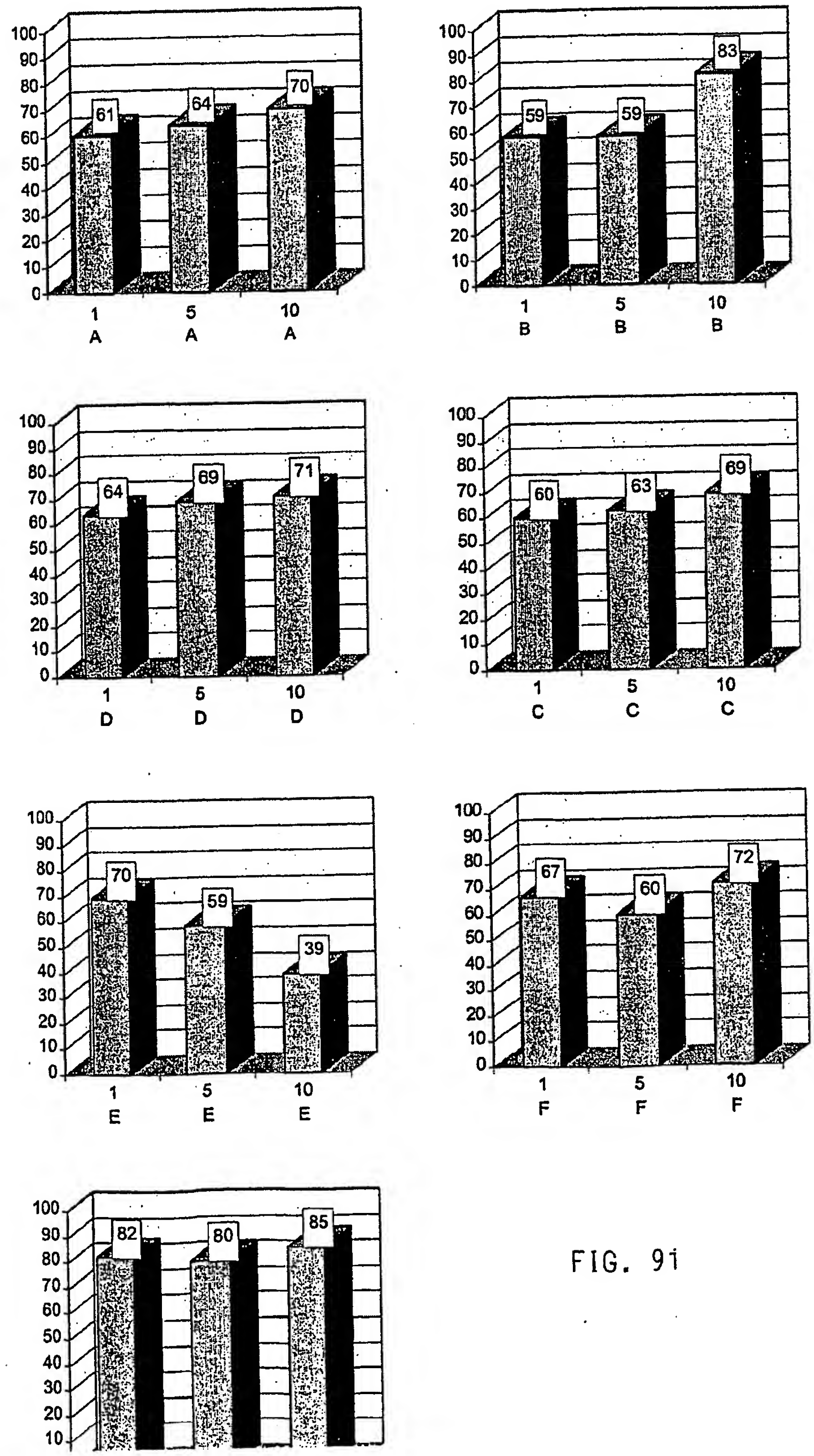


FIG. 10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71
1 D
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FIG. 9i

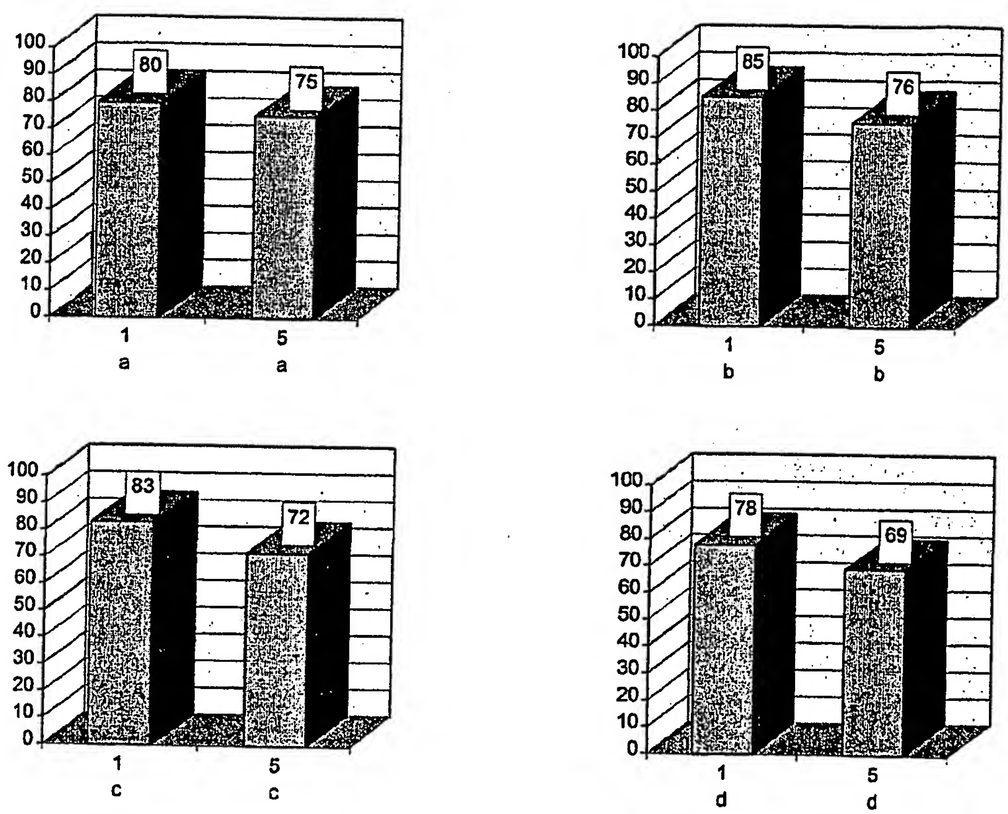
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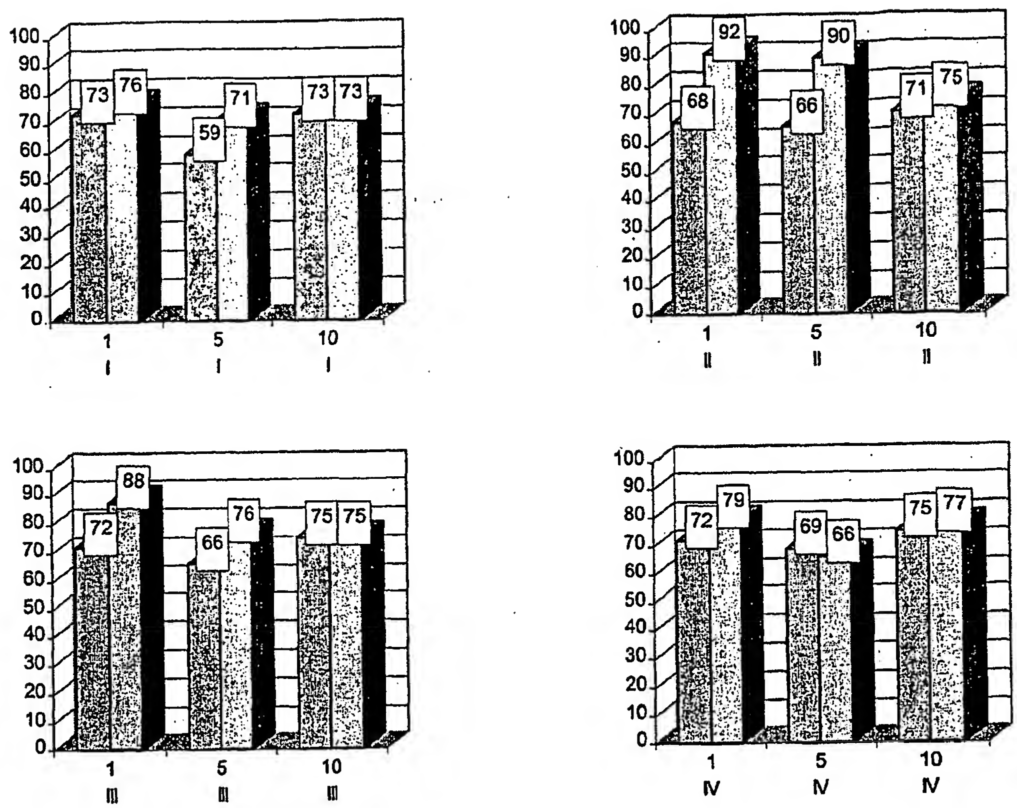
FIG. 9ii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75
1
III
5
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FIG. 11

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 November 2001 (22.11.2001)

PCT

(10) International Publication Number
WO 01/087052 A3

(51) International Patent Classification[7]: A01K 63/04, B01F 3/04, 5/04 // C02F 3/26

(21) International Application Number: PCT/NO01/00207

(22) International Filing Date: 18 May 2001 (18.05.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
20002602 19 May 2000 (19.05.2000) NO
20004513 8 September 2000 (08.09.2000) NO

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(72) Inventors; and
(75) Inventors/Applicants (*for US only*): NÆSS, Anders [NO/NO]; Måltrostveien, N-1555 Son (NO). GAUSEN, Martin [NO/NO]; N-6650 Surnadal (NO).

(74) Agents: ONSAGERS AS et al.; P.O. Box 265 Sentrum, N-0103 Oslo (NO).

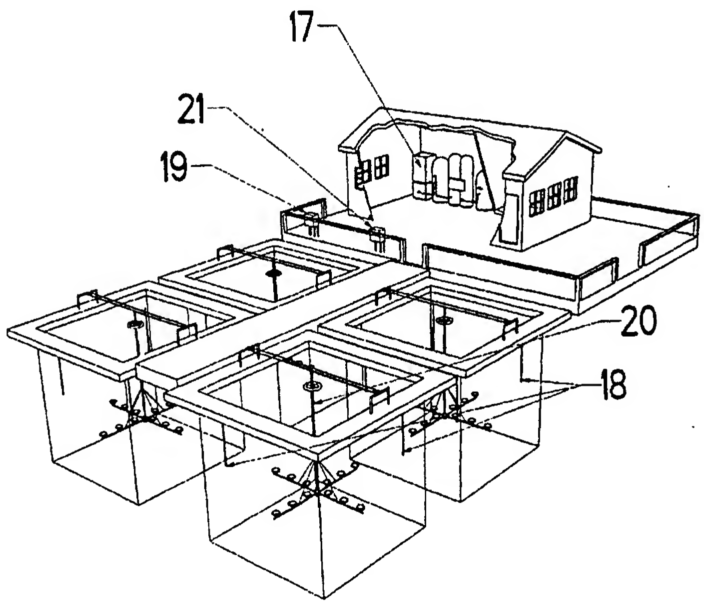
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

[Continued on next page]

(54) Title: DEVICE FOR OXYGENATING WATER



(57) Abstract: The present invention relates to a device for oxygenating water in aquaculture plants for marine organisms in the sea, together with a method for using the device. The invention provides for the supply of substantially pure oxygen which is distributed via a specified system to the water. Here given devices arrange for the formation of oxygen microbubbles with an oxygen partial pressure which is such that the oxygen passes into the water in the aquaculture plant. The distribution of oxygen is adjusted in relation to the water's oxygen saturation.

WO 01/087052 A3

(88) Date of publication of the international search report: 8 August 2002

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NO 01/00207

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A01K63/04 B01F3/04 B01F5/04 //C02F3/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A01K C02F B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 893 337 A (SEVIC BOHUMIL) 13 April 1999 (1999-04-13) column 1, line 40 - line 45 column 2, line 16 - line 32 column 3, line 20 - line 23 column 3, line 54 - line 64 ---	1,2, 9-11, 15-17 1,10
Y	JP 56 061934 A (TAIKISHA KK) 27 May 1981 (1981-05-27) see international classification figure 1 ---	1,10
Y	US 4 271 099 A (KUKLA THOMAS S) 2 June 1981 (1981-06-02) column 1, line 65 -column 2, line 17 figure 11 ---	1,10

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
26 November 2001	03. 06. 2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jens Waltin

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NO 01/00207

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 49 107890 A (...........) 14 October 1974 (1974-10-14) see classification (FI) figures 1-8 ---	1,10
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 06, 22 September 2000 (2000-09-22) & JP 2000 084588 A (FANCHENGAN OCEAN SCIENCE &TECHNOL DEV CENTER), 28 March 2000 (2000-03-28) abstract; figures 1,2 ---	1,6-8, 10,14
A	GB 824 376 A (DISTILLERS CO YEAST LTD) 25 November 1959 (1959-11-25) page 2, line 110 - line 115 ---	4
A	SE 458 424 B (SPIRAWORK OY) 3 April 1989 (1989-04-03) abstract ---	5,13
A	DE 200 02 392 U (UTA UMWELTTECHNIK) 10 August 2000 (2000-08-10) figures 1,2 -----	1-5, 9-13, 15-17

International application No.
PCT/NO 01/00207

INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

As a result of the prior review under R. 40.2(e) PCT,
no additional fees are to be refunded.

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☒ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 3-5,10 and 12,13

   The first invention concerns diffusers mounted on a suitable device, and optionally equipped with a pressure equaliser. This invention is further described in claims 3-5,10 and 12,13.

2. Claims: 6-8 and 14

   The second invention concerns ejectors, optionally equipped with a non-return unit. This invention is further described in claims 6-8 and 14.

INTERNATIONAL SEARCH REPORT

nation on patent family members

International Application No
PCT/NO 01/00207

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5893337	A	13-04-1999	FR	2746258	A1	26-09-1997
			CA	2200655	A1	22-09-1997
			DK	796556	T3	08-05-2000
			EP	0796556	A1	24-09-1997
			ES	2141584	T3	16-03-2000
			JP	3184778	B2	09-07-2001
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JP 56061934	A	27-05-1981	NONE			
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			SE	8400110	A	25-07-1984
DE 20002392	U	10-08-2000	DE	20002392	U1	10-08-2000

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